# A Chandra and XMM–Newton Investigation of the Nuclear Accretion in the Sombrero Galaxy (NGC4594)

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## The Sombrero Galaxy

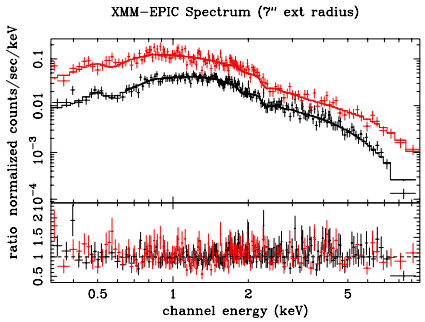
- Sa galaxy, D = 9.4 Mpc
- Detected in the X–rays by Einstein and classified as LINER (Halpern & Steiner 1983)
- Hosting a SMBH with M~$10^9$ $M_\odot$(Kormendy et al. 1996)

## X–ray Observations

- XMM–Newton on December 28, 2001; $T_{exp}$ = 40ks
- Chandra ACIS–S on May 31, 2001; $T_{exp}$ = 18.7ks.

## XMM Spectrum of the LINER Nucleus

- Spectrum from 7" radius, corresponding to ~0.3 kpc at the distance of the galaxy




*Sombrero nuclear EPIC MOS (black) and pn (red) spectra and fit residuals for a simple absorbed power–law model.*

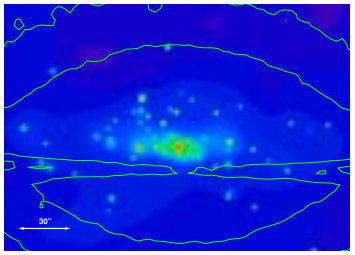
- Fitting the data with an absorbed power–law model *(XSPEC: wabs(wabs(pow)))*

| Parameter | Value |
|---|---|
| $\chi^2/dof$ | 381.2/320 |
| Intrinsic $N_H(cm^{-2})$ | $1.8 \pm 0.1 \times 10^{21}$ |
| Photon Index | $1.88^{+0.06}_{-0.01}$ |
| 0.5-2 keV flux (erg $cm^{-2}$ $s^{-1}$) | $1.5^{+0.1}_{-0.2} \times 10^{-11}$ |
| 2-10 keV flux (erg $cm^{-2}$ $s^{-1}$) | $1.3 \pm 0.1 \times 10^{-11}$ |
| 0.5-2 keV luminosity (erg $s^{-1}$) | $5.7 \pm 0.4 \times 10^{39}$ |
| 2-10 keV luminosity (erg $s^{-1}$) | $1.4 \pm 0.1 \times 10^{40}$ |

- The simple absorbed power–law model is a good representation of the 7" spectrum
- We set an upper limit on the equivalent width of the 6.4keV iron Kα line of 145 eV (narrow line), and of 296 eV (broad Gaussian line with σ = 0.43 keV, as in Sy1s; Nandra et al. 1997)

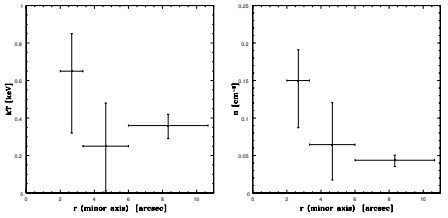
## Mass Accretion Rate

- Chandra's high angular resolution provides unique information on the circumnuclear regions, as near as 2 arcsec from the nucleus (< 100 pc)




*Adaptively smoothed Chandra ACIS–S image (0.3–10 keV band) of the Sombrero galaxy with superimposed optical contours from the DSS. North is up East to the left.*

- Spectra were extracted from 3 elliptical annuli centered on the nucleus
- Using a deprojection technique implemented in XSPEC we derived the density and the temperature profile of the ISM surrounding the nucleus.




*Temperature profile (left panel) and density profile (right panel) for the Sombrero galaxy. Errorbars indicate the 90% confidence interval.*

- With T and n we can estimate the accretion onto the SMBH following the Bondi (1952) theory of steady, spherical and adiabatic accretion:

$$\dot{M}_{Bondi} = 8.2 \times 10^{25} M_8^2 \, T_{0.5}^{-3/2} \, n_{0.11} \; g \; s^{-1} \approx [0.008 - 0.037] \dot{M}_{Edd} / yr$$

(the range in $\dot{M}_{Bondi}$ derives from the errors on T and n)

and

$$L_{acc} = \eta \dot{M}_{Bondi} c^2 \simeq [1.3 - 26] \times 10^{43} \; erg \; s^{-1}$$

- $L_{acc}$ ~ 200 $L_{bol}$ << $L_{Edd}$ (~$10^{47}$ erg/s)

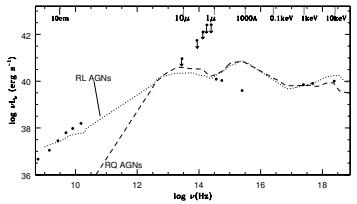
## Why Is the Nucleus So X–ray Faint?

### 1. Heavily obscured emission?

- Compton thick material surrounding the nucleus and heavily absorbing the X–ray emission (as in Seyfert 2) could explain the very sub–Eddington luminosity.
- However no sign of heavy obscuration is present both in the XMM spectrum and in HST V–I image (Emsellem & Ferruit 2000).
- The absence of a strong 6.4 keV iron fluorescence line (EW>1keV) rules out this hypothesis definitively.

### 2. Downsized AGN?

- Some similarities are observed between the Sombrero's nucleus and luminous AGNs (Xray/radio luminosity ratio, X–ray power–law photon index, $L_X$–$L_{H\alpha}$correlation),
- Sombrero's SED lacks the 'blue bump' observed in luminous AGN and attributed to the accretion disc. This is a feature common to some low luminosity AGN (Ho 1999)
- However $L_{bol}$<< $L_{acc}$ rules out efficient disc accretion
- Other differences between Sombrero's nucleus and Sy1's:
  - Absence of a strong (~300eV) 6.4 keV emission line and lower X–ray luminosity
  - Lack of X–ray flux variability
  - Small $N_H$, inconsistent with the absence of prominent broad line emission




*Sombrero's Spectral Energy Distribution (SED)*

### 3. Radiatively inefficient accretion?

- Accretion may proceed at ~$\dot{M}_{Bondi}$ but with a low radiative efficiency, through an ADAF (Narayan & Yi 1995)
- The absence of an iron line, the X–ray Γ ~ 1.9 and the radio to X–rays ratio are consistent with simple ADAF predictions.
- However a simple ADAF modeling for Sombrero, with the $\dot{M}_{Bondi}$ estimated here, shows that the radio flux is largely overestimated (Di Matteo et al. 2001)
- Radiatively inefficient accretion including outflows or convection, and normalized to match the observed X–ray luminosity, is expected to show a deficit of radio emission

### 4. Jet dominated emission?

- Recent radio observations show that a strong jet presence is a common feature of LINERs (Nagar et al. 2001) and recent modeling of low luminosity AGNs (Falcke et al. 1999; Yuan et al. 2002) suggests that the higher wavelengths may be also dominated by the jet emission
- Some features of the Sombrero's SED, like a flat radio spectrum (Hummel et al. 1984) and a peak in the IR region, could be in agreement with the predictions of the jet dominated model. This model has been applied recently to explain the whole SED of the LINER in the elliptical galaxy IC1459 (Fabbiano et al. 2003)
- In this modeling the jet is by far the dominant sink of power (~0.1 $L_{acc}$ in the form of kinetic and internal energy)

### 5. Low mass supply?

- The mass supply to the central SMBH could be much lower than $\dot{M}_{Bondi}$, because accretion is not adiabatic and/or steady
- The ISM could be heated by a central source (Binney 1999; Di Matteo et al. 2003) or by inverse Compton scattering of hard photons (Ciotti & Ostriker 2001), decreasing accretion on the SMBH.
  This is consistent with higher kT in the center, $\dot{M}_{Bondi} < \dot{M}_*$, low $L_X$/ $L_B$, all features present in Sombrero, suggesting partial winds (Ciotti et al. 1991, Fabbiano et al. 1992)

Further details can be found in Pellegrini et al. (2003) ApJ in press (astro–ph/0307142)